Turbulent diffusion of a passive scalar through a turbulent kinetic energy step in two and three dimensions

December 16, 2010

1 Introduction

2 Mean scalar diffusion

Mean scalar profiles, scalar mixing layer thickness

3 Higher order moments

Variance, Skewness, kurtosis, spectra, ...
Note: 3D uniform energy to be computed

4 Derivative statistics

Variance, skewness, kurtosis

5 Conclusions

FIGURES:

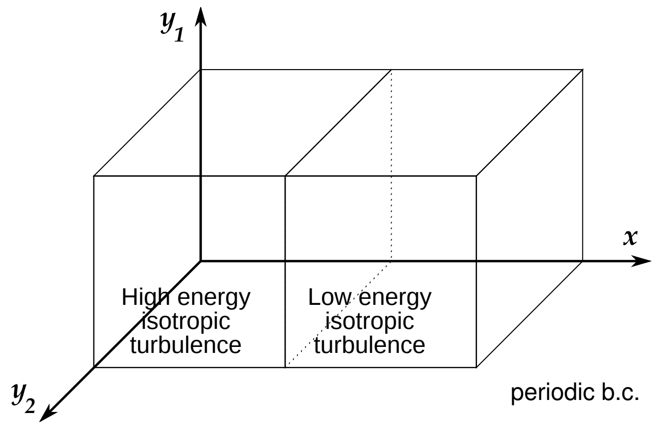

Figure 1: Scheme of the flow (computational domain and initial conditions in the 3D simulations, obvious modifications for the 2D simulations). The ratio of the energy E_1 in the high energy region and E_2 in the low energy region is $E_1/E_2 = 6.6$. The scalar in introduced in the low energy region only.

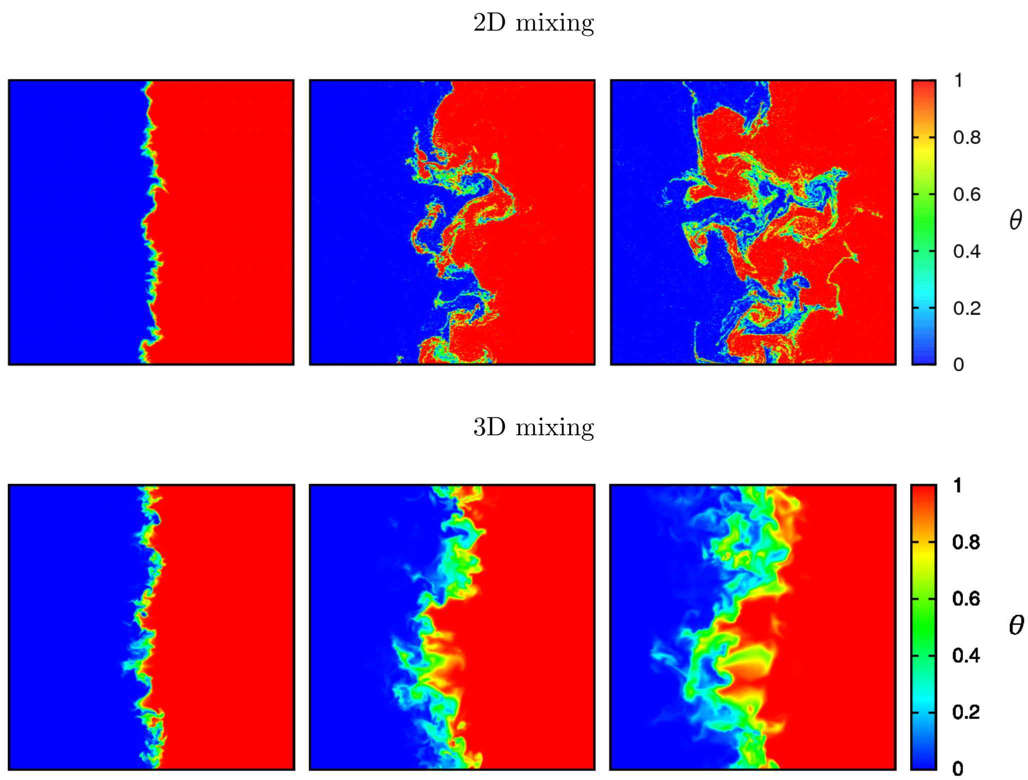

Figure 2: Visualization of the scalar field. In both cases, the three different instants correspond from left to right at $t/\tau = 1, 5, 10$ respectively. The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy isotropic region (on the left).

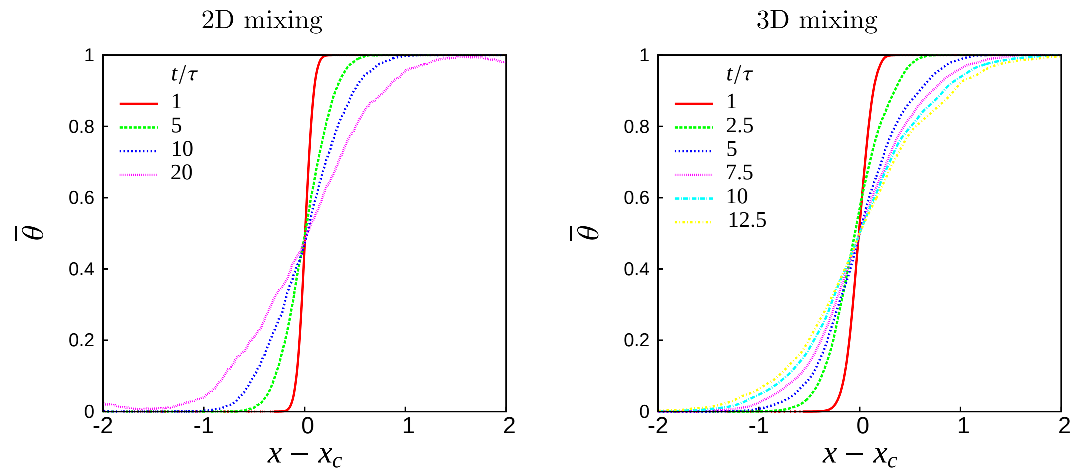

Figure 3: Mean scalar profiles. x_c is the centre of the mixing layer.

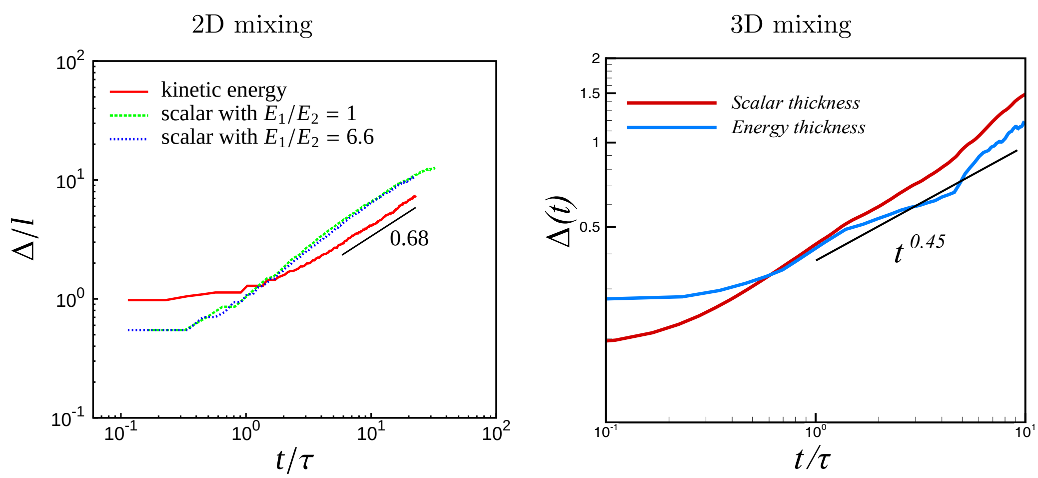

Figure 4: Mixing layer thickness. The scalar layer thickness Δ_θ is defined as the distance between the points where $\overline{\theta}$ is equal to 0.25 and 0.75. The energy layer thickness is defined as the distance between the points where the normalized turbulent kinetic energy $(E-E_2)/(E_1-E_2)$ is equal to 0.25 and 0.75. For the 2D case, the value of $\Delta(t)$ has been normalized by the integral scale which is about 1/80 of the total domain. The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy region. The power law exponents refer to the energy layer thickness. *** NOTES: (1) there is almost no difference in the mean scalar and scalar variance when the energy gradient is removed ($E_1 = E_2$). However, differences can be observed in higher moments. (2) the 2D time evolution of Δ_θ is in good agreement with Lagrangian statistics, in the sense that $\Delta_\theta^2 \sim \langle (X(t) - X(0))^2 \rangle$, where $X(t)$ is the particle position. ***

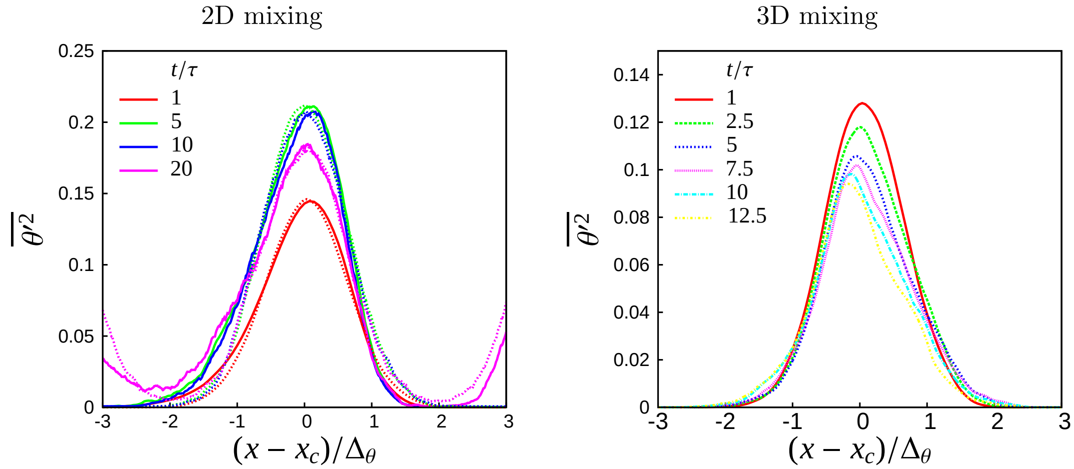

Figure 5: Scalar variance. For the 2D case, the full lines correspond to the case where $E_1/E_2 = 6.6$ and the dashed lines to the case where $E_1/E_2 = 1$. The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy region (on the left). *** NOTE: there is almost no difference in the mean scalar and scalar variance when the energy gradient is removed ($E_1 = E_2$). However, differences can be observed in higher moments. ***

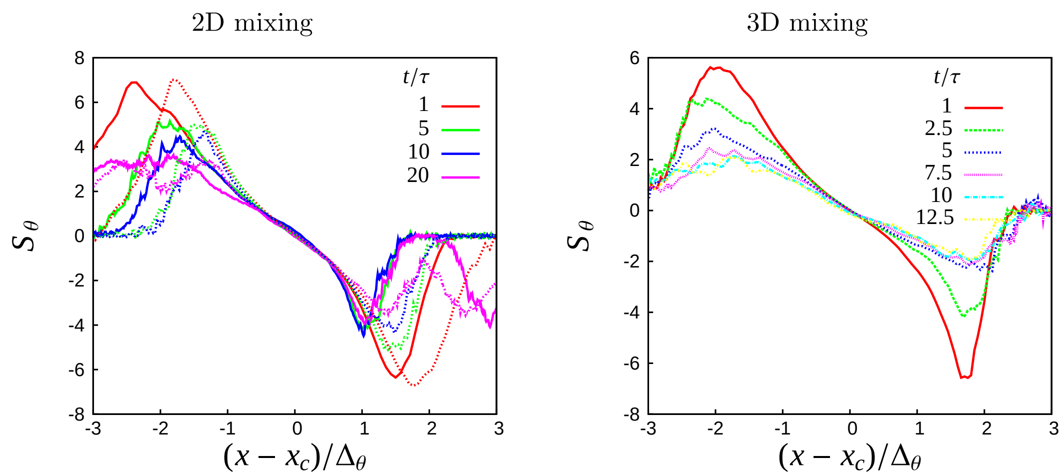

Figure 6: Scalar skewness. For the 2D case, the full lines correspond to the case where $E_1/E_2 = 6.6$ and the dashed lines to the case where $E_1/E_2 = 1$. The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy region (on the left). *** NOTE: there is almost no difference in the mean scalar and scalar variance when the energy gradient is removed ($E_1 = E_2$). However, differences can be observed in higher moments. ***

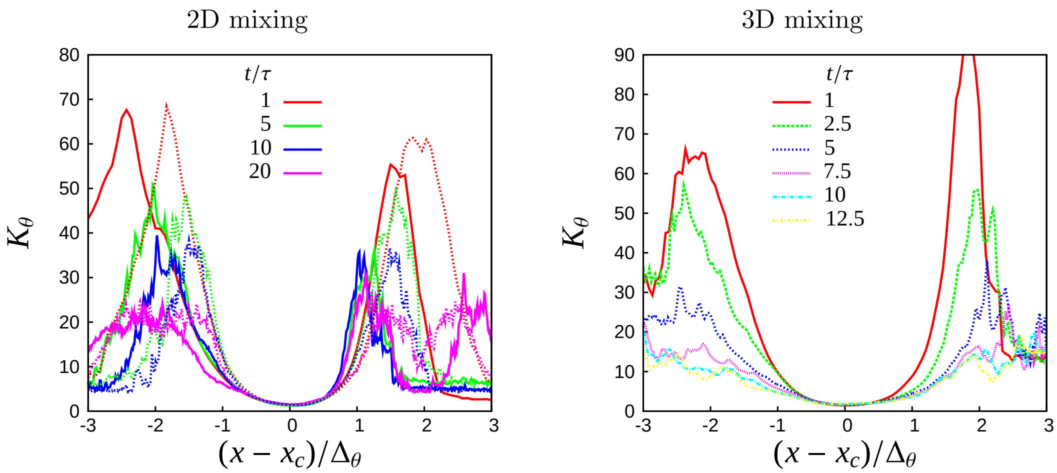

Figure 7: Scalar kurtosis. For the 2D case, the full lines correspond to the case where $E_1/E_2 = 6.6$ and the dashed lines to the case where $E_1/E_2 = 1$. The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy region (on the left).

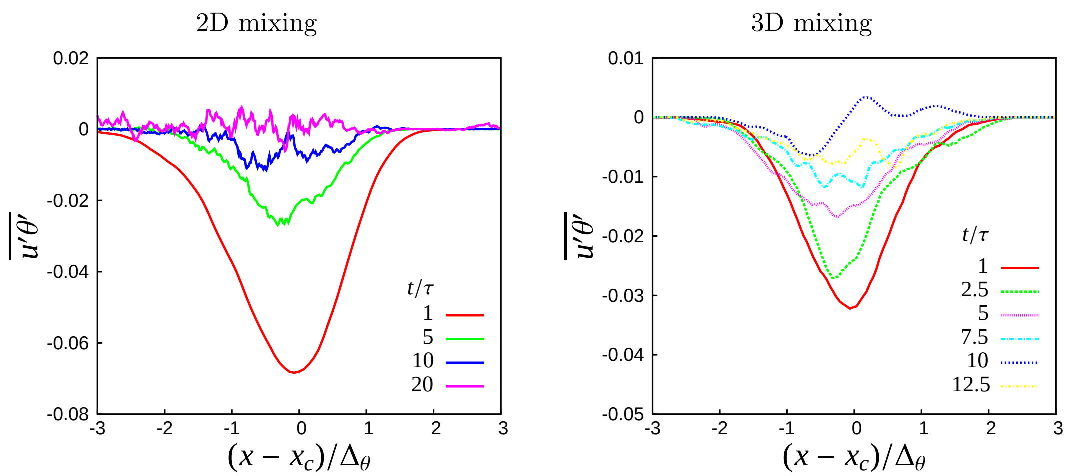

Figure 8: Scalar flow $\overline{u'\theta'}$.

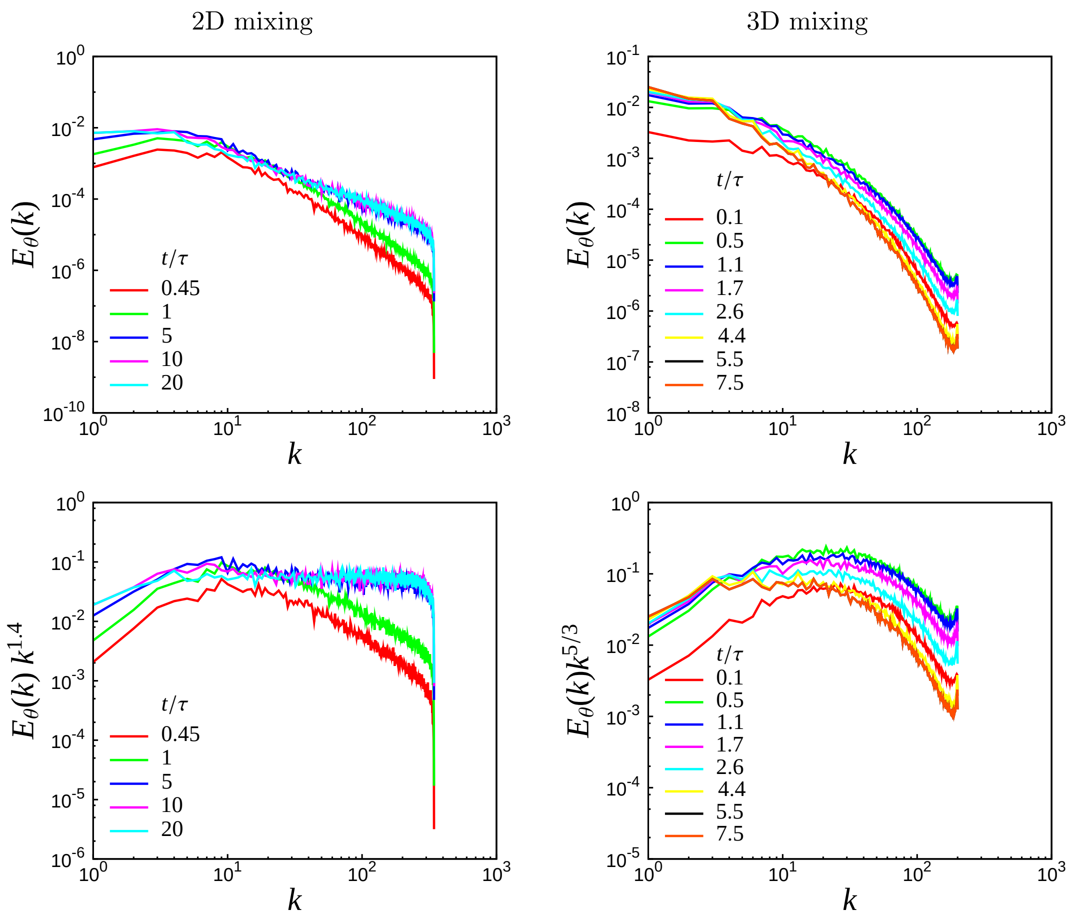

Figure 9: One-dimensional scalar spectra and compensated spectra. For the 3D case, the spectra have been compensated by $k^{5/3}$; in 2D, the scaling of the scalar spectra ($k^{1.4}$) differs strongly from the kinetic energy one (k^{-3}). The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy isotropic region.

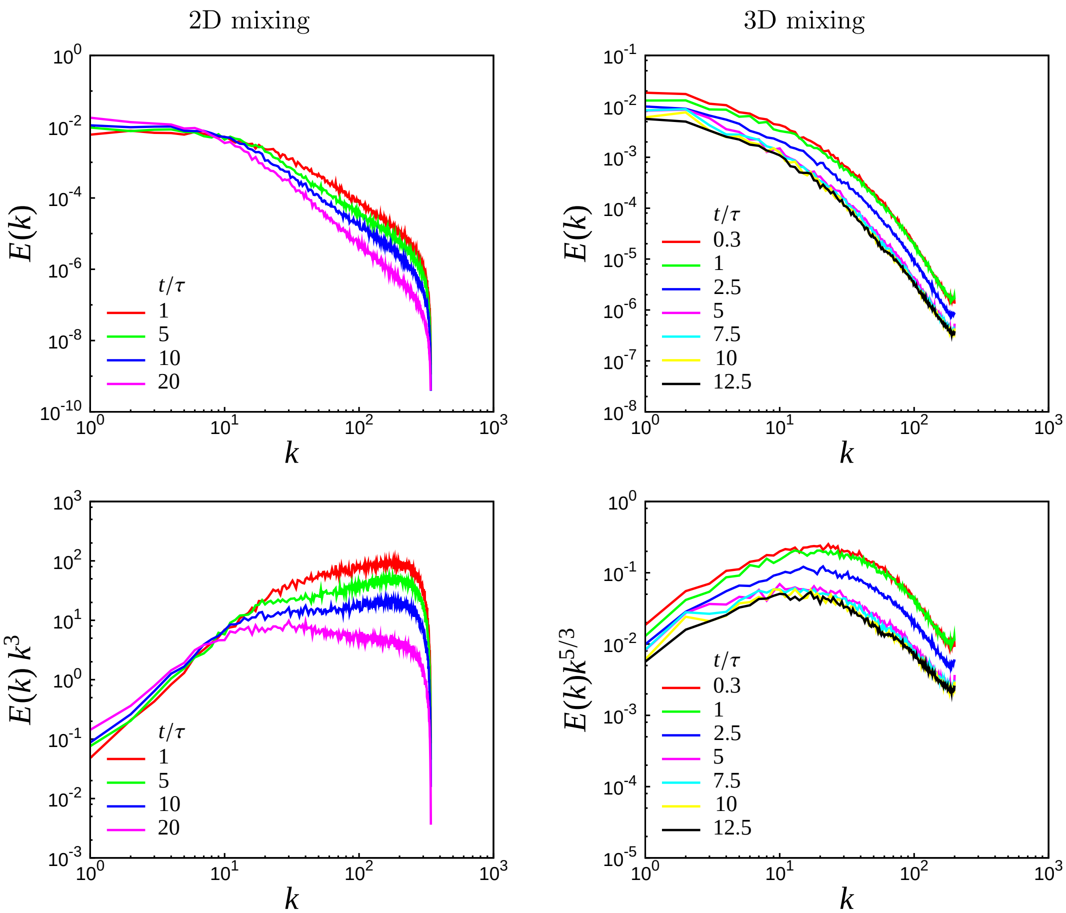

Figure 10: One-dimensional longitudinal velocity spectra and compensated spectra in the centre of the mixing layer ($x = x_c$). The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy isotropic region.

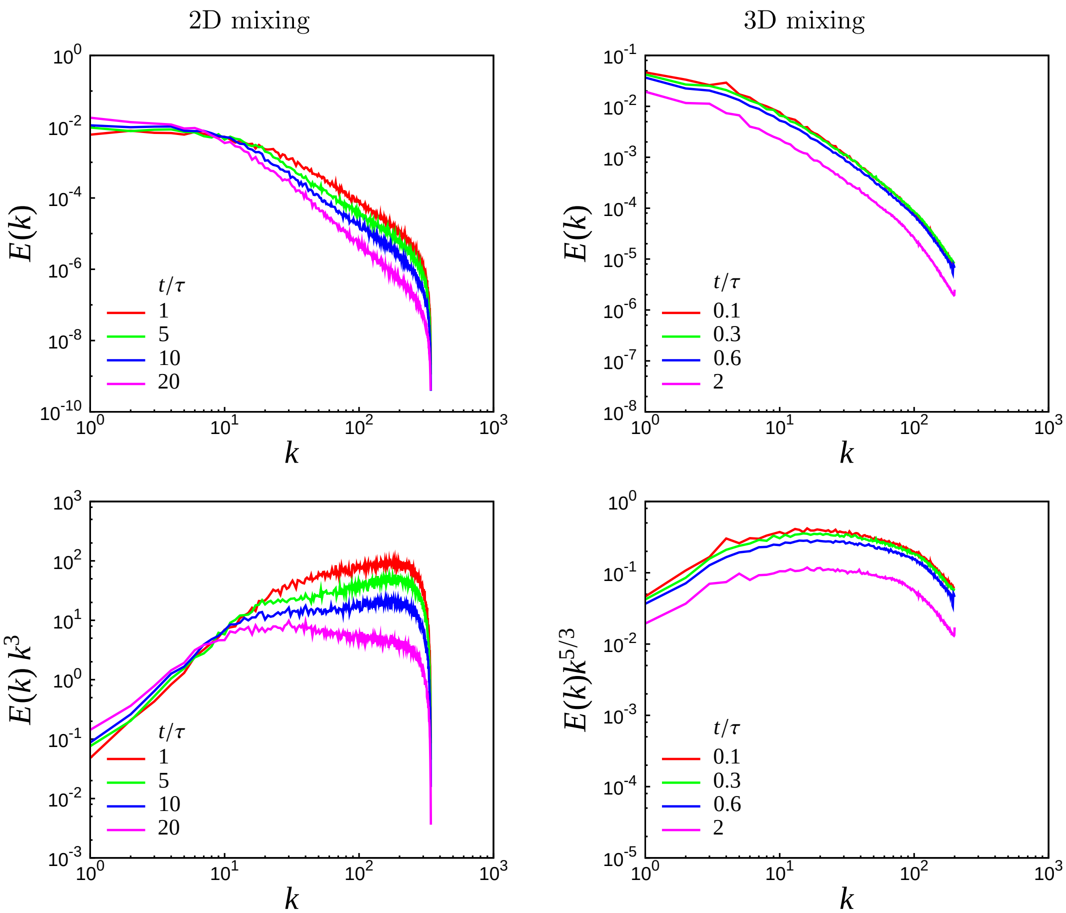

Figure 11: One-dimensional longitudinal velocity spectra and compensated spectra in the high energy isotropic region (on the left of the domain). The 3D simulation has an initial Reynolds number $R_\lambda = 150$ in the high energy isotropic region.

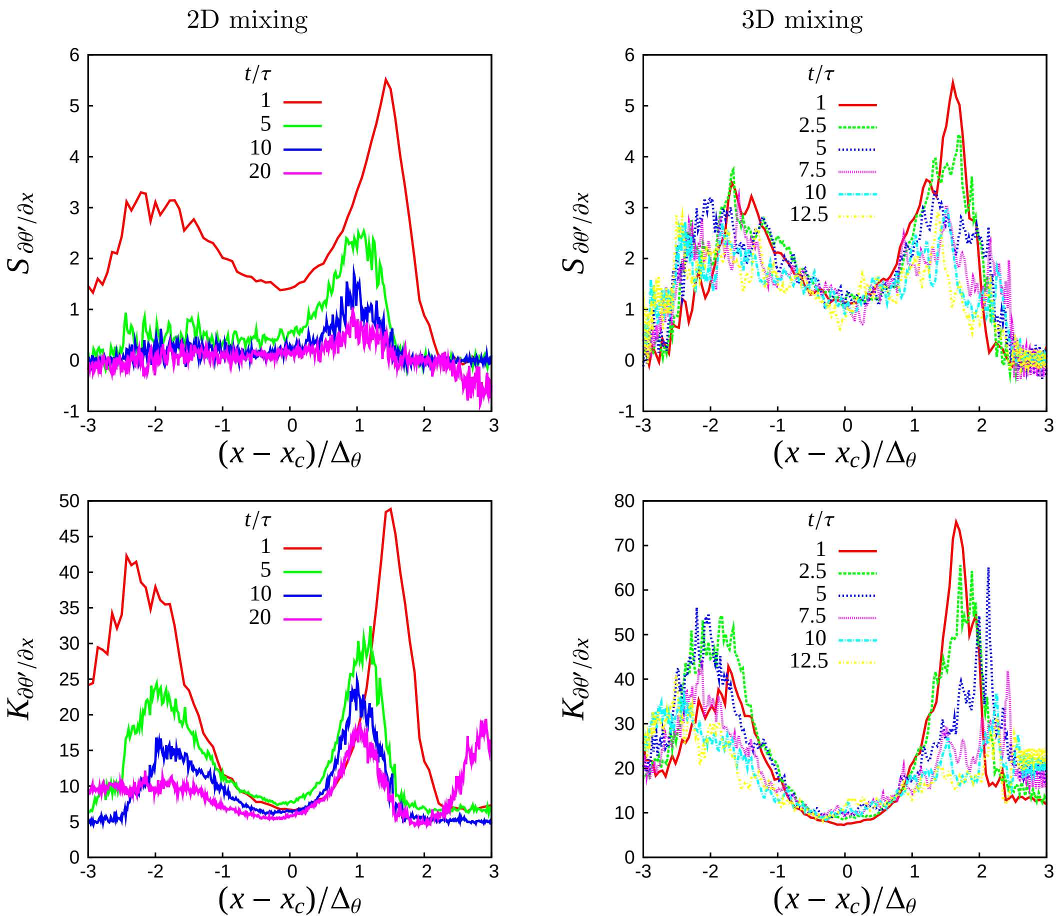

Figure 12: Skewness and kurtosis of the derivative of the scalar fluctuations in the inhomogeneous direction.